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Mars Orbiting Pulsed Doppler Wind Lidar for Characterization of Wind and Dust

by

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Opportunity

NASA plans to explore Mars. Both the manned portion and the robotic lander portion of the exploration of Mars require the landing of greater mass than before, and with greater precision than before. These goals are impeded by the lack of knowledge, both climatology and real-time, of the air density, wind, and dust in the atmosphere. The dust in the atmosphere is a direct threat to the lander, and an indirect threat since it affects air density by absorbing sunlight.

One Ingredient of the Solution

It would be very beneficial to know more about the climatology of Mars' atmosphere, especially about the density, wind, and dust. This knowledge could be greatly enhanced by placing a pulsed Doppler wind profiling lidar in Mars orbit. The pulsed lidar could provide horizontal wind velocity and relative dust concentration vs. altitude over the whole planet.

The technology to do this has been under development by NASA for about 20 years. NASA Langley has developed a high pulse energy 2-micron solid-state laser for the mission of measuring earth's winds from earth orbit. The earth wind mission has recently been endorsed by the NRC's earth science decadal survey of Jan. 2007.

The coherent or heterodyne detection type of Doppler wind lidar has many advantages over other detection schemes including greater sensitivity (less photons needed for equal wind measurement performance). The greater sensitivity will be needed to achieve the small volume, mass and power needed for Mars orbit. The greater sensitivity derives from the direct measurement of frequency shift of the return light. Tone detection in noise is a proven concept. The other Doppler wind lidar detection schemes rely on counting photons from multiple detectors to calculate the wind velocity. Good accuracy requires a multitude of photons.

NASA Langley has demonstrated separately 1.2 J of pulse energy, all conductive cooling, and compact, rugged lidar packaging. Sophisticated computer simulations of the earth orbit mission show that the coherent Doppler lidar would only require 250 mJ of pulse energy at 5 Hz pulse rate. The margin between demonstrated and required energy permits derating of the laser to achieve greater reliability and lifetime.

The solution to global winds from earth orbit had been found to be a hybrid Doppler lidar, that is, both a coherent and direct detection lidar sharing the job. This elegant solution derives from the inability of the coherent lidar to measure very far above the boundary layer since the aerosol content of earth's atmosphere falls rapidly with altitude; and from the inability of the direct lidar to measure below a certain altitude since the atmosphere absorbs the 355 nm wavelength light at low altitudes.

The solution for Mars is probably different. Mars has greater aerosol (dust) content than earth. We have performed a preliminary simulation of Mars winds performance and have found that wind measurement to higher altitudes is much easier on Mars for the coherent lidar than it is on earth. The second reason for a different solution is the photon inefficiency of the direct detection type of Doppler lidar. Mission studies for the hybrid solution in earth orbit show the coherent lidar uses about 10% of the total hybrid lidar electrical power. This photon inefficiency probably rules out direct detection for Mars orbit.

Recommendation

The laser design team that succeeded so well at making the high energy laser for earth orbit winds is still assembled and available to tackle the Mars application. A study should be performed to more thoroughly trade the coherent lidar system's power, mass, and volume; against the size of the technology development needed and against the performance in Mars orbit to profile wind and relative dust concentration.

Options

By increasing the lidar scanner's complexity, the vertical wind profile could also be measured.

The 2-micron laser wavelength tuning range overlaps many carbon dioxide absorption lines. The Differential Absorption Lidar technique of obtaining carbon dioxide mixing ratios on earth is under study. Since Mars atmosphere is primarily carbon dioxide, an intriguing possibility would be to use the DIAL technique on Mars to obtain density profiles.

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